Zero Emission Cargo Transport II

San Pedro Bay Ports Hybrid & Fuel Cell Electric Vehicle Project

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South Coast Air Quality Management District

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(This presentation does not contain any proprietary, confidential, or otherwise restricted information) [Project ID # VSS158]

ZECT II Overview

Timeline

- Project Award: 10/1/14
- Contractor Kickoff: 6/16/15
- Project Completion: 9/30/18

Contractors & Projects

- BAE/CTE - Fuel cell range extended drayage truck
- BAE/GTI - CNG hybrid with catenary accessibility
- TransPower - Fuel cell range extended drayage truck
- U.S. Hybrid - Fuel cell powered drayage truck
- International Rectifier – Diesel hybrid with quick charge capability

Barriers & Challenges

- Fueling Infrastructure: Availability and location
- Costs: Fuel Cells, batteries and infrastructure
- System Integration: Safe and efficient deployment of the technology

Budget

- DoE: $10,000,000
- Funding partners: $7,183,979
- Contractors: $3,075,841

Total Cost:$20,259,820

ZECT II Goals

- Reduce criteria pollutants in South Coast Air Basin by reducing diesel emissions from transportation and movement of goods
- Accelerate introduction and penetration of zero and near-zero emission fuel cell and hybrid technologies in cargo transport sector

ZECT II Approach and Strategy

- Require contractors to have experience with fuel cell or battery electric truck and bus development
- Require contractors to partner with a major OEM
- Use existing fueling infrastructure and set aside funds for temporary infrastructure
- Leverage previous and ongoing project's vehicle technologies and infrastructure

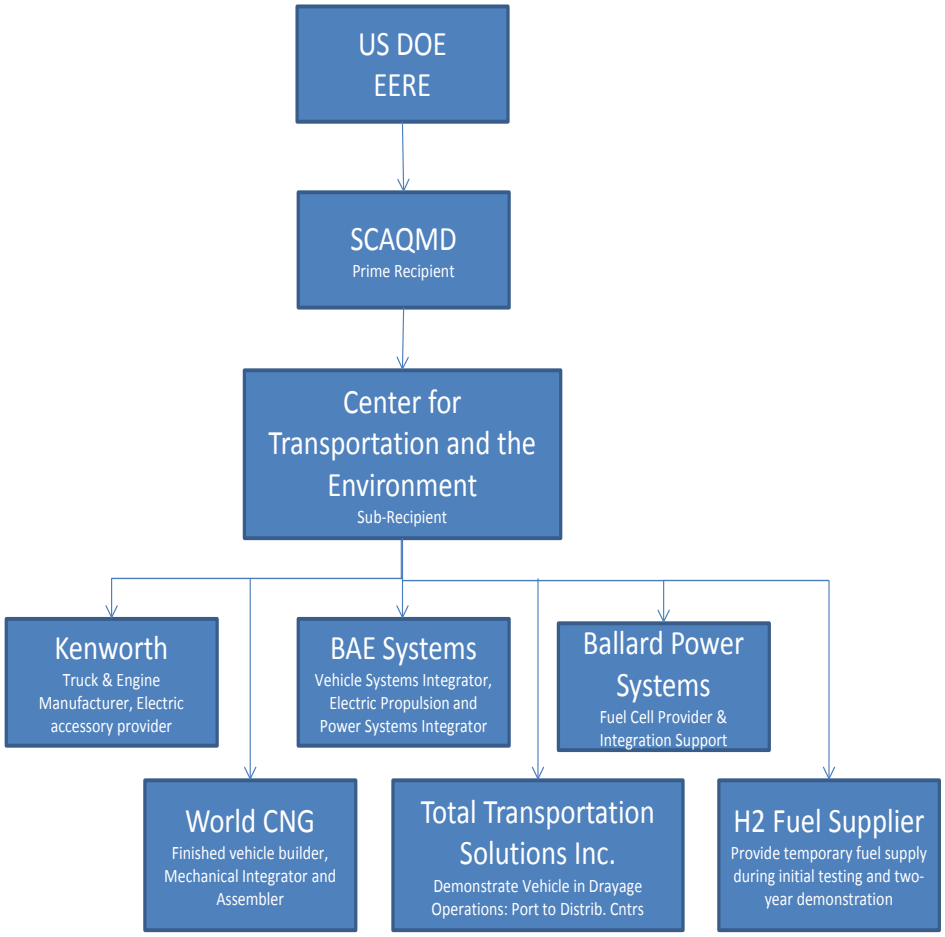
BAE Electric Drayage Truck with Fuel Cell Range Extender

American Fuel Cell Bus Experience

OEM Partner: Kenworth

Collaboration: BAE/CTE Project Team

- **BAE Systems**
  - Electric propulsion system
  - Prime system integrator
  - Fuel cell bus experience
- **Ballard**
  - Fuel cell manufacturer
- **Kenworth**
  - Vehicle manufacturer
- **World CNG**
  - Vehicle builder
- **TTSI**
  - Vehicle operator
- **Center for Transportation and the Environment (CTE)**
  - Project manager
- **Fuel Supplier:** TBD



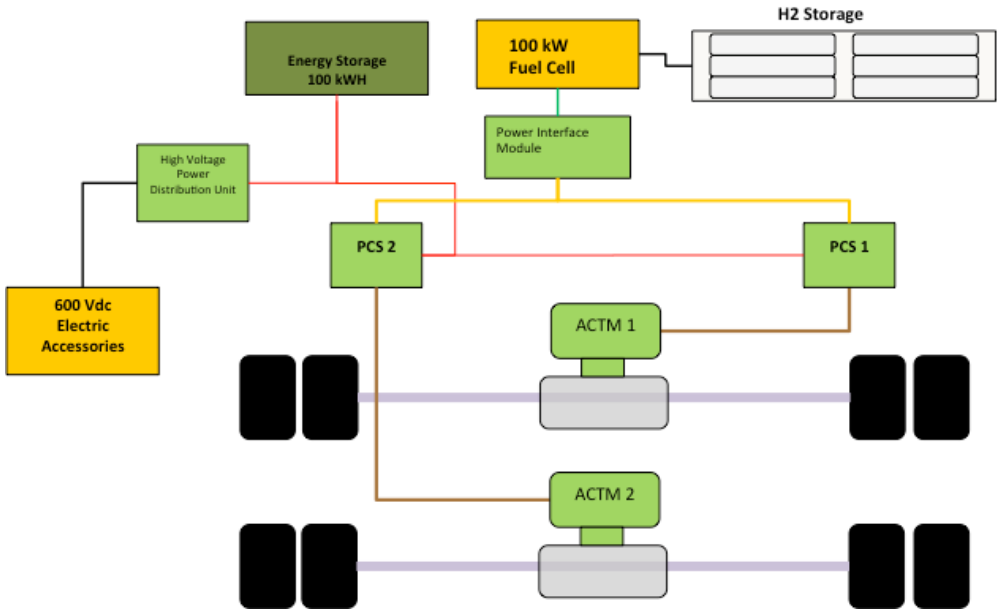
KENWORTH BAE SYSTEMS BALLARD WORLDCNG TTSI

BAE Electric Drayage Truck with Fuel Cell Range Extender

- **Primary Power Source**
  - 100 kWh Lithium technology batteries
- **Auxiliary Power Unit (Range Extender)**
  - 100 kW Fuel Cell providing power to charge batteries
- **Electric Drivetrain**
  - Drivetrain will be based on BAE Systems HybriDrive® Series propulsion system
  - 2 dual propulsion control systems
  - 2 180 kW AC traction motors

Hydrogen Fuel

- 30 kg Onboard hydrogen fuel storage system



TransPower Electric Drayage Truck with Fuel Cell Range Extender

BC Transit Fuel Cell Bus Experience

OEM Partner: International

TransPower Electric Drayage Truck Approach

Using existing ElecTruck developed in ZECT I project as a platform…

Build an extended range zero-mission truck using fuel cell technology

Hydrogenics HyPM™ Fuel Cell

TransPower Electric Drayage Truck Performance Goals

Road performance capabilities of current ElecTruck™ battery-electric trucks

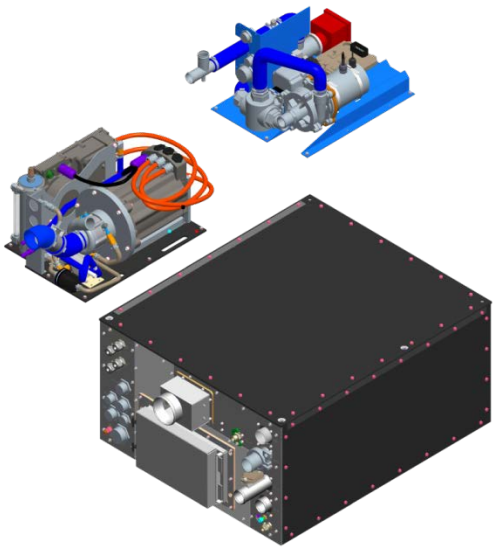
- Haul 80,000 lb. loads
- Sustain 65 mph highway speeds
- Match or surpass diesel truck acceleration and gradeability

Extend operating range

- 40 miles all electric range
- 200 miles total range without refueling or recharging

U.S. Hybrid Electric Drayage Truck with Fuel Cell Range Extender

Component Manufacturer For Electric and Fuel Cell Powertrains Experience



OEM Partner: Kenworth

US Hybrid FC Truck Overview

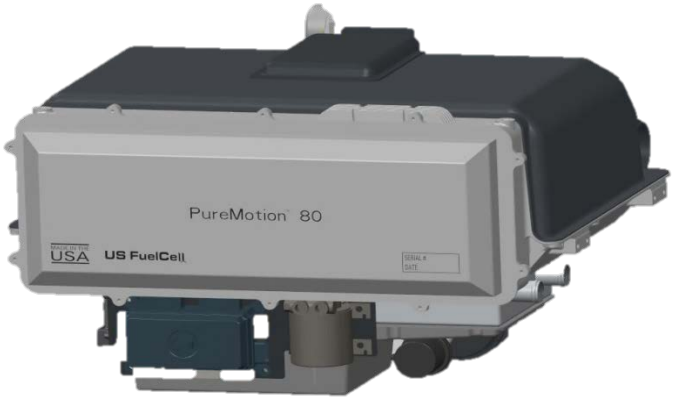
Development of 2 Fuel Cell Electric Plug-In Drayage Trucks using ZECT I Electric Truck Experience

- Fuel cell dominant
- US Hybrid 80kW power plant
- 320kW direct electric drive
- 26kWhr battery system
- Expected range 150-200 miles
- 20kg @ 350bar
- 6.6kW on-board charger

Vehicle OEM: International

Customer: TTSI

PureMotion™ 80
Fuel Cell APU



BAE CNG Hybrid Electric Drayage Truck

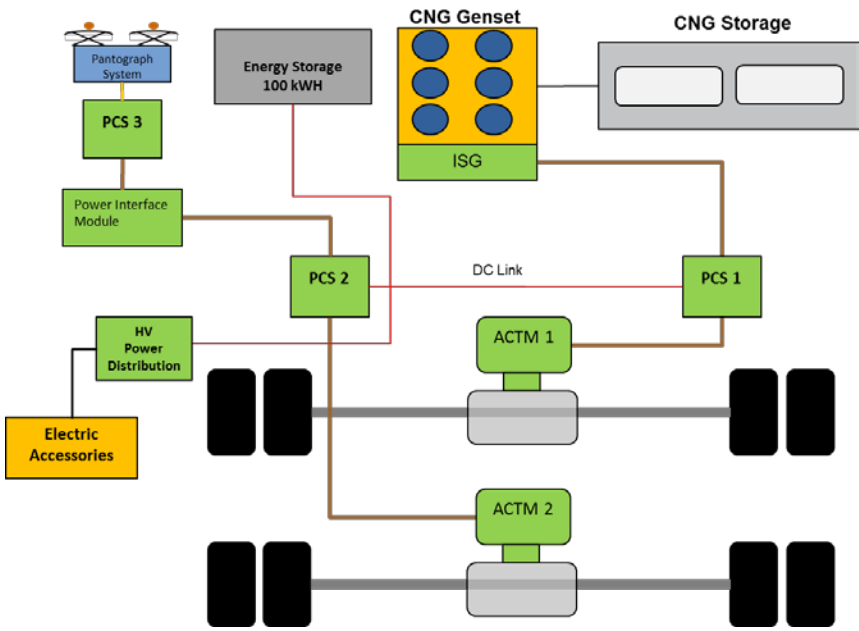
American Fuel Cell Bus Experience

OEM Partner: Kenworth

BAE CNG Hybrid Electric Drayage Truck

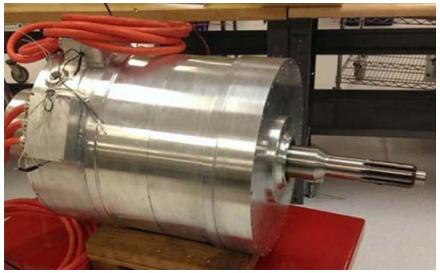
Solution:

- Battery, catenary and a CNG genset to provide near-zero and zero emission heavy duty truck operation
- CNG genset used as an APU for range extension via battery charging
- A 50 – 100 kWh energy storage system
- The propulsion system based on BAE systems HDS300 with one SCU to control the system operation
- Two drive motors one on each rear axle to increase propulsion capability



International Rectifier (IR) Diesel Hybrid Electric Drayage Truck

Component Manufacturing and Integration Experience



OEM Partner Peterbuilt

IR Diesel Hybrid Drayage Truck

Zero-emissions bubble around port area

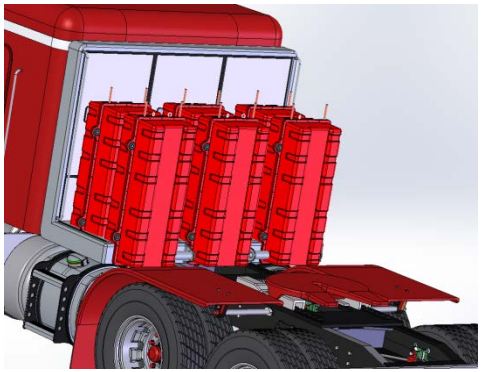
- **Goal:** Create Zero Emissions Bubble around Ports of LA & Long Beach and surrounding communities
- **Technology:** Conversion of existing trucks to PHEV with Ultra-Fast-Charge
  - All-electric operation in and near ports for zero emissions
  - Hybrid-electric operation outside ports and communities for fuel savings
  - Ultra-fast charging for maintaining established fleet logistics and operations

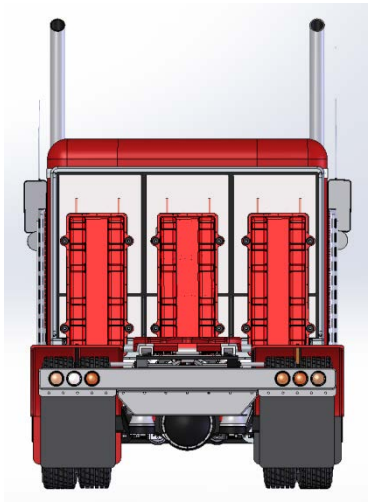
IR Vehicle Specifications

EV Architecture: Parallel PHEV

Modes of Operation:

1. All-electric drive mode
2. Hybrid mode
    a) Motor-assisted start and acceleration
    b) Brake regeneration
    c) Engine start/stop
3. Zero-emissions Idle: IR EADS™ Electric Accessory Drive System



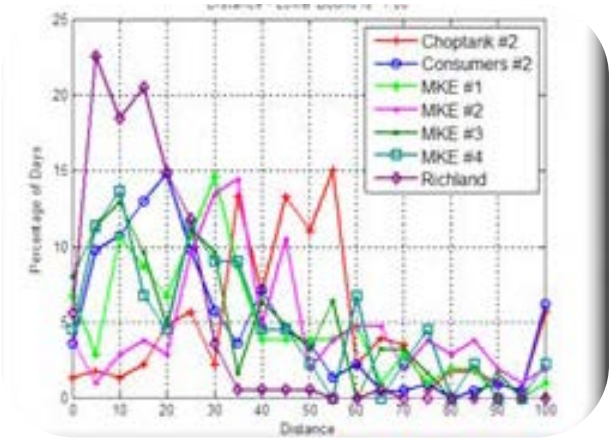


Recharging modes

1. Ultra-fast charging (15-20 minutes)
2. Diesel generation
3. Regenerative braking

ZECT II Performance Evaluation

- Capital, operating, and maintenance costs
- Reliability and performance advantages and challenges
- Impact of technology and requirements on existing goods movement operations
- Infrastructure requirements of large scale adoption and deployment



Performance Measurement

Technology Impact

Infrastructure Deployment

ZECT II Status & Future Activities

- Contracts are in process with SCAQMD
- Some technical teams are proceeding on project tasks
- Vehicle design, analysis, equipment purchase and integration will be completed in the first year for IR, U.S. Hybrid and TransPower projects
- Vehicle design and analysis will be completed within second year for both BAE projects
- Equipment purchase and integration as well as vehicle testing and validation will be accomplished in the following year for the BAE projects
- All projects will conduct 24 month on-road demonstration and data collection after vehicles are completed.

ZECT II Summary

- ZECT II goal: reduce criteria emissions from goods movement by accelerating introduction and penetration of fuel cell and hybrid technologies
- Seven zero emission vehicles to be developed and demonstrated
- Experienced integrators assures timely, safe and efficient deployment of technologies
- Leveraging previous projects maximizes future benefits
- OEM involvement will help develop a path to commercialization of zero emission technology



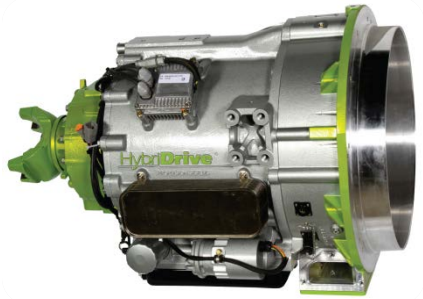

Response to Reviewers Comments

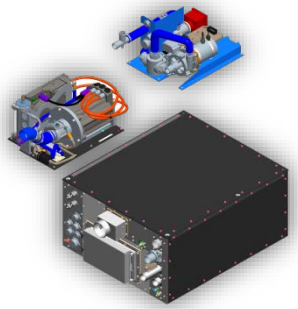
- This project is a new start.

Technical Backup Slides

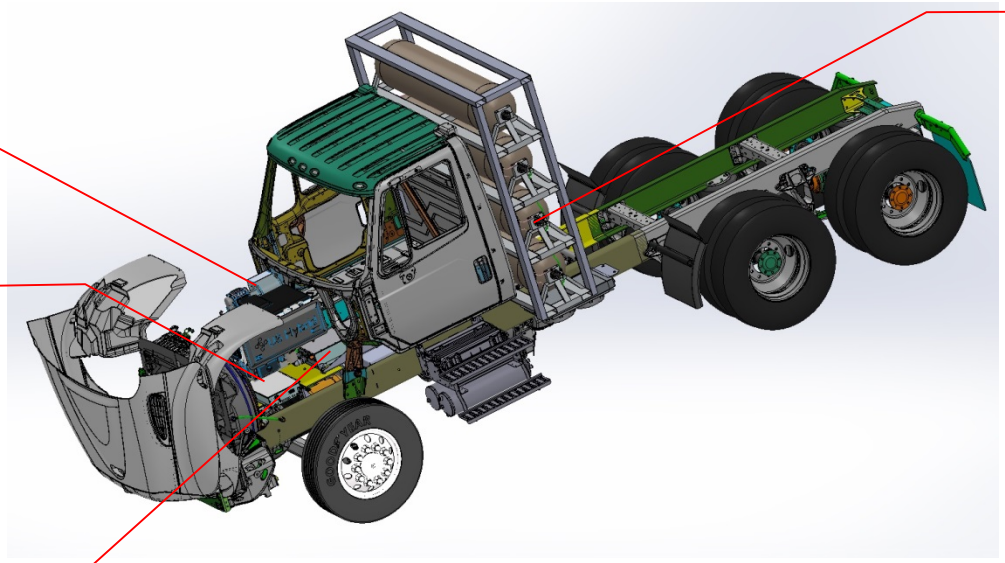
Electric Drayage Truck with Fuel Cell Range Extender Specifications

Platform	Kenworth T370, Class 8
GVWR	80,000 lbs.
Fuel Cell Make	Ballard
Fuel Cell Size	HD-7, 100 kW (Net 80 kW)
Battery Capacity	100 kWh
Drive System	BAE Systems HybriDrive®
Traction Motors	2x 180 kW (approx. 500 hp)
Range (per fueling)	Approx. 100 miles
H_2 storage	30 kg @350 bar (25 kg useable)
Type	Battery dominant
Fuel Supply	Temporary Mobile Fueling & existing stations





US Hybrid FC Truck Configuration

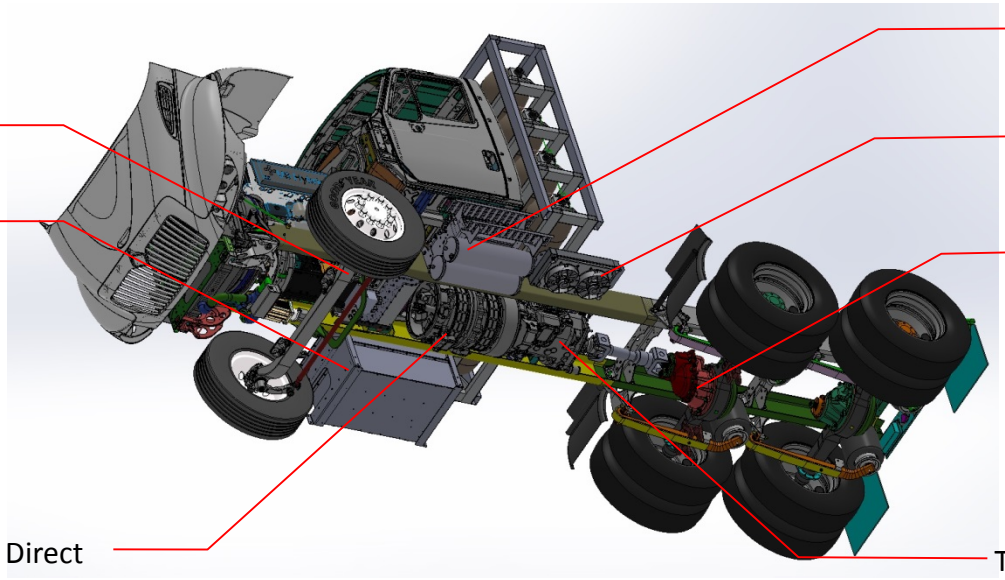


Hydrogen Tanks

US Hybrid Integrated PureMotion™ 80 Fuel Cell APU

US Hybrid Auxiliary Drive

US Hybrid DC-DC Converter



Compressed Air Tanks

US Hybrid Motor Control Unit and Charging System

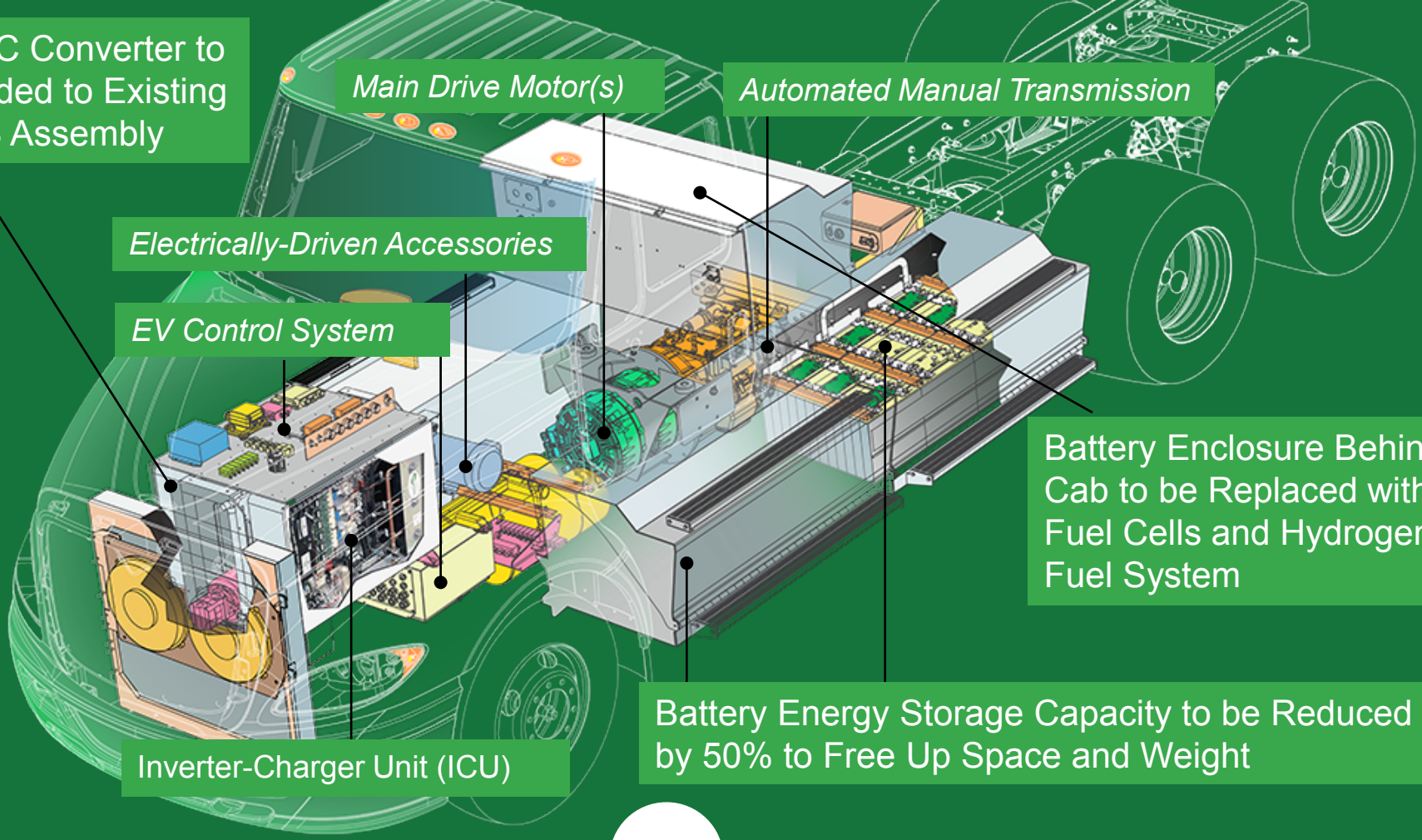
Electronics Cooling Unit

26kWhr Battery System

Differential

US Hybrid 320kW Direct Electric Traction Drive

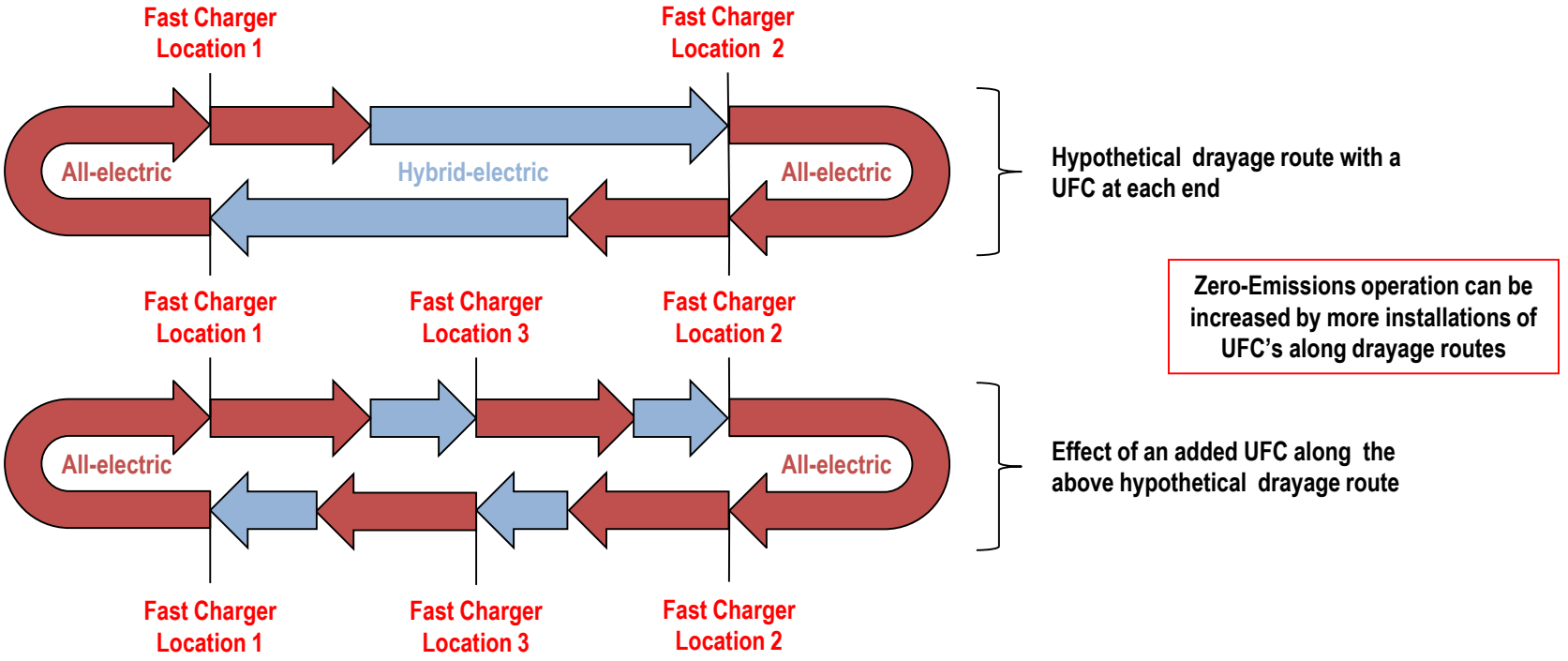
Transmission



How existing ElecTruck™ platform will be modified to achieve desired goal

IR PHEV Concept

- Drayage routes can vary greatly: One size battery pack cannot serve all route types
- Ultra-Fast Charging (15-20 minutes) with hybrid electric operation enables use of smaller battery packs
- Strategy: Place Ultra-Fast Chargers (UFC) near pollution impacted areas to enable all-electric-range



CNG Hybrid Electric Drayage Truck Key Performance Parameters

- Modes of operation:
  - Battery electric: Zero emissions near port operation
  - Catenary: Zero emissions operation
  - CNG: Extends range beyond all-electric-range
- Range per fill: ~ 150 miles
- Fuel economy: significant improvements over current state-of-the-art CNG trucks
- Top Speed: 70 mph
- Power: 300 HP continuous (charge sustaining mode), 480 HP (charge depleting mode) and 536 HP peak